NI

TECHNICAL MEMORANDUM

November 23, 1964

To: John Baude & R. J. Lofthouse

From: Paul D. Hess

Subject: Electrical Monitoring and Control Subsystem Development Plan Activity 200

Distribution: J. L. Platner, D. F. Ghere, R. E. Lochen, J. R. Hurley, J. E. Ward, C. Martin, G. Johnson

1. ASSIGNMENT

The individuals to whom this memorandum is directed are assigned the design effort responsibility of evolving the design specification drawing (s), and/or functional diagrams of the subject subsystem (Activity 200 - 395). In conjunction with this and other critical component areas continuous surveillance must be maintained so that recommendations can be made at the earliest possible dates, where requests for GFE back-ups are essential.

In addition, the tests planned or evolved, which will follow the path from Event 200 through 405 on to 580, shall be performed and reported on along with periodic subsystem design reviews. A concerted attempt should be made to meet all dates set forth in the Part III PERT Program Plan.

2. FUNCTION

The Electrical Monitoring and Control Subsystem (EMCS) will consist of all electrical components such as connectors, relays, sensors, electrical and mechanical devices required to start, stop, maintain regulation and to maintain proper conditions of the FCA. The EMCS will be a compact and seperate package from the FCA with electrical cables connecting the EMCS and the FCA.

The EMCS will be capable of accomplishing the above functions automatically and/or manually. Suitable instrumentation readout for the Instrumentation Subsystem will be provided so that complete manual operation of the FCA may be accomplished. The instrumentation readout will include reactant and cavity pressure, total voltage and current, % KOH and temperature. The characteristics of the readout equipment will be integrated with the Instrumentation Subsystem. Suitable indicating devices will be employed so that positions of relays and valves of critical components can be determined.

3. STATUS

The first units will be built using a Bud Portable Cabinet 12 H x 14 1/8 W x 18 D and a Bud aluminum chassis for mounting the hardware. Prints 49-400-134-401, Electrical Control Assembly and 49-200-206-501, List of Material illustrates the layout and operator capabilities. The Fuel Cell Protection and Control System single line diagram 49-300-221 and its associated outline are included for an overall description of the system.

The following items are part of the EMCS and the function and operation of each is outlined.

1.	Master Control	4
2.	Auxilliary Master Control	4 x
3.	Water Removal Controller	20 Wx
4.	Temperature Controller	20 Tx
5.	Purge Controller	20 HOx
6.	DC-DC Inverter	
7.	Voltage Regulator	90
8.	Instantaneous Overcurrent Device	76
9.	Undervoltage device	27 x

1. Master Control

The Master Control consists of the mode switch, function switches, manual override switches and associated circuitry for sequential shutdown and interlock. The mode switch will be used to select either STANDBY, MANUAL or AUTOMATIC operation. The function switch will be used to START, STOP or LOAD the system. The enclosed Master Control single line diagram illustrates the interconnection between the switching, controllers, valves and protection circuits.

The FCA may be started by depressing START if the FCA was shutdown by the STOP switch or the key operated interlock must be reset first if the FCA was shutdown by the protection device. Then mode selected MANUAL/STANDBY/AUTOMATIC determines the operation of the controllers and the position of the valves.

Auto:

Assuming AUTO mode was selected, the inlet reactant valves would be opened, the temperature controller would sense the need for heating or coolant and automatically control temperature. Load would not be applied until the LOAD switch was depressed. The under-temperature device would prevent applying load until operating temperature had been reached. Then depressing the LOAD switch would cause the load to be applied after a time delay during which the FCA would receive an initial purge, H_2O cavity controller energize and purge controller would energize. In the event of overcurrent (110 amps) or excessive purging (more than 4 consecutive non-scheduled purges) the load will be removed. The load will be reapplied by depressing the LOAD switch. In the event one of the following conditions exist the protection shutdown device will initiate a sequential shutdown and trip the key operated interlock.

1. Over-temperature
2. Under-temperature
3. Short circuit current
4. Low voltage
5. Loss of fan power

The sequential shutdown will cause the following conditions in order:

1. Remove load
2. De-energize H_2O cavity controller & close valve
3. Close reactant valves
4. De-energize temperature controller & close valve
5. De-energize purge controller & close valve

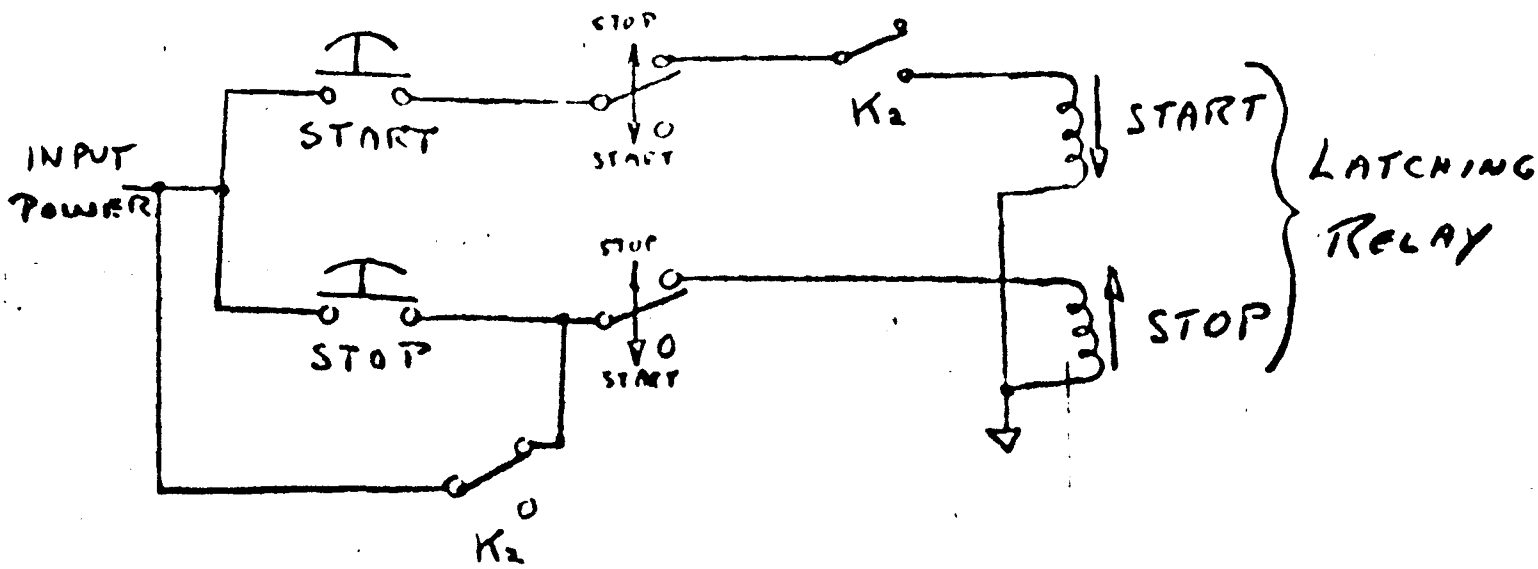
Manual:

Assuming MANUAL mode was selected, the position of the manual override switches would determine whether the valves were controlled automatically by the controllers, opened or closed. The load could be applied without a time delay and purging if at operating temperature, by depressing the LOAD switch. The protection shutdown and sequential shutdown will operate the same as in AUTO. The temperature would automatically be maintained.

Standby:

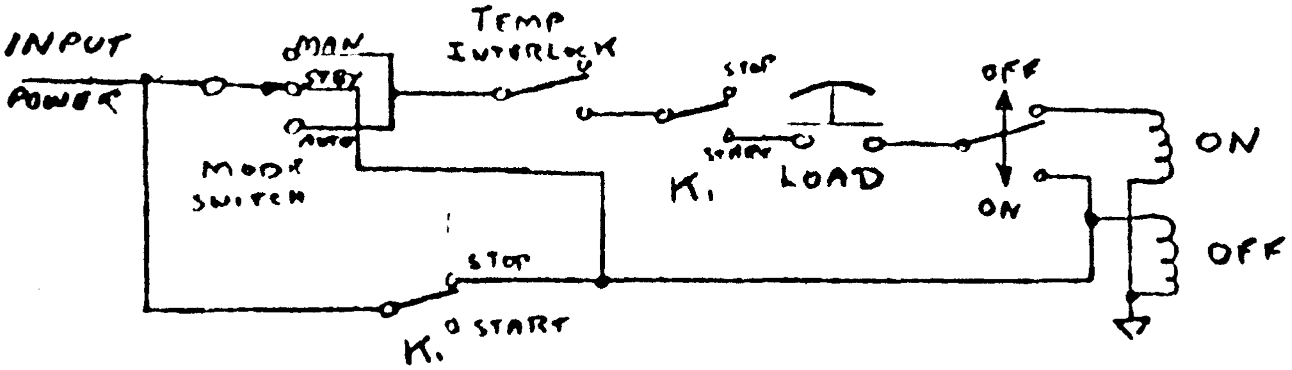
Assuming STANDBY mode was selected, the inlet reactant valves would be opened, temperature maintained, H_2O cavity controller de-energized and valve closed and the load removed. When starting the FCA from a shutdown condition, the temperature controller would sense the need for heating or coolant and automatically maintain temperature. The protection devices would be in effect.

The START & STOP functions will utilize one latching relay for both functions. One position of the relay will represent start and the other stop. The latching relay contacts will then control the valves and controllers dependent upon the mode of operation. The latching relay operation is shown in the following diagram



K_2 represents the relay contacts associated with the protection shutdown device. K_2 cannot be reset except by using the key operated interlock. Therefore, K_2 forces the system to STOP and prevents STARTING again until the key interlock is reset.

The LOAD function will utilize a latching relay to control the valves and controllers dependent upon mode of operation. The LOAD latching relay operation is shown in the following diagram.



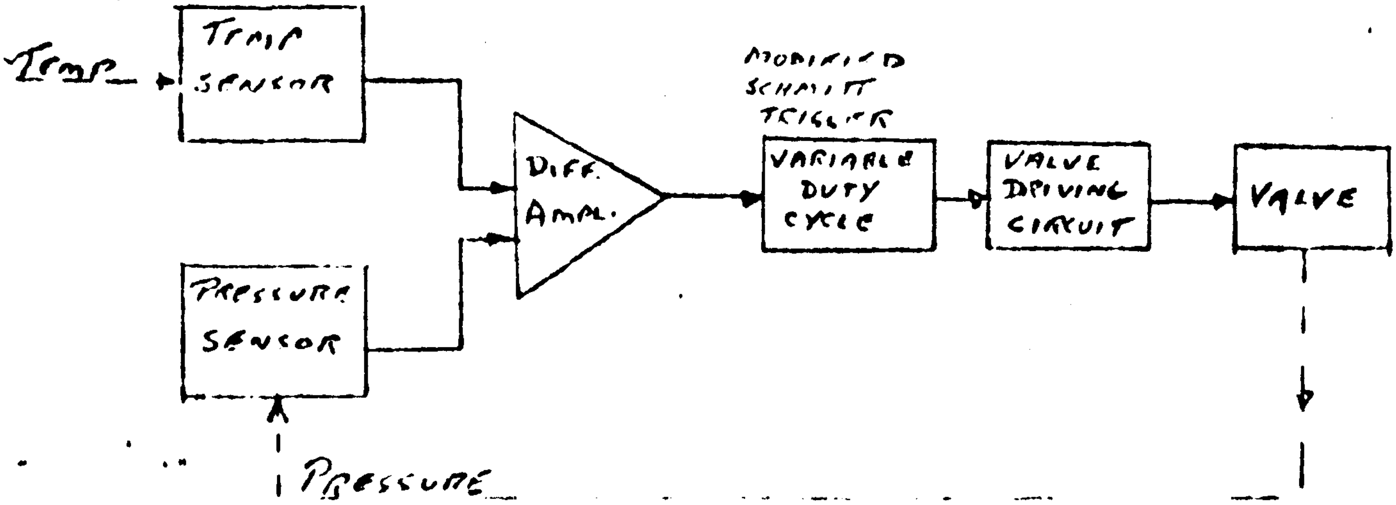
The LOAD latching relay cannot be turned on unless the mode switch is in MANUAL or AUTO, FCA is up to temperature, the START/STOP relay (K_1) is in START position. Then depressing LOAD turns the relay on.

2. Auxilliary Master Control

The Auxilliary Master Control will be a subassembly which will contain all the latching relays and electro-mechanical devices. It will be controlled by the Master Control and will transmit the information to the valves and controllers

3. Water Removal Controller

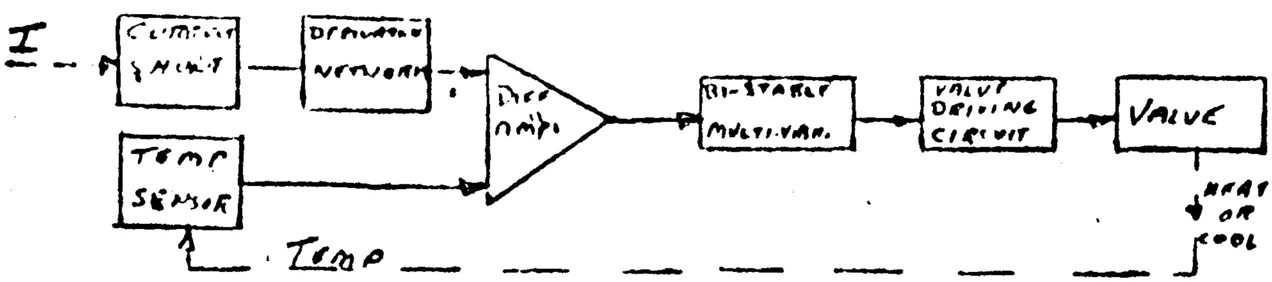
This unit will maintain the FCA at a preset KOH concentration independant of temperature and load. The controller block diagram follows



The unit utilizes the temperature characteristics of the transistor for temperature sensing and a potentiometer type transducer for the pressure sensor. These signals are fed into a microminiature differential amplifier and the output is a function of pressure and temperature. The voltage into the variable duty cycle device determines the duty cycle of the valve.

4. Temperature Controller

This unit will maintain the FCA at operating temperature. It will be capable of determining a need for heating or cooling and maintaining either condition. The controller block diagram follows.



The temperature controller receives a sustained signal from a thermistor located in a suitable place within the FCA.

A transient signal is also received from the shunt of the FCA which senses the magnitude of the total output current. The combined signals control a differential amplifier, and a bi-stable multivibrator, which has a clock frequency of 1 minute and a variable duty cycle extending into the regions of fully "on" to fully "off".

The current signal as taken from the FCA shunt, and before reaching the input terminals to the differential amplifier, is conditioned by a derivative network consisting of a capacitor and adjustable resistor. The time constant of the RC derivative network is made variable by means of the resistor and permits the selection of a temporary override of the output of the temperature sensing thermistor in accordance with the overall FCA thermal time constant. A maximum time constant of 5 to 6 minutes has been provided.

Incipient demand supervision over the slow acting thermistor is provided by the duo-directional characteristics of the derivative network, and a zero center microammeter permits observation of the proper function of the circut.

The temperature controllers thermistor will be used to control the preheating cycle of the FCA system by providing a seperate output switching circuit for the heaters.

5. Purge Controller

The purge controller will be capable of performing scheduled and non-scheduled purging. The scheduled purging will be on an ampere hour basis and the non-scheduled purge will be a function of rate of voltage decay. The ampere hour element of the unit consists of a conventional unijunction staircase wave generator with modifications. A straight line relationship between millivolt input from main current shunt and pulse frequency is obtained over the range of 1 amp to 120 amps. Additional countdown circuitry features a microminiature decade counter driving a set of static purge valve program controls.

6. DC-DC Inverter

The DC-DC inverter will be used to isolate the power for the controllers from the FCA power. This is required because a shunt is being used to monitor current. The inverter will be a conventional DC-DC inverter

7. Voltage Regulator

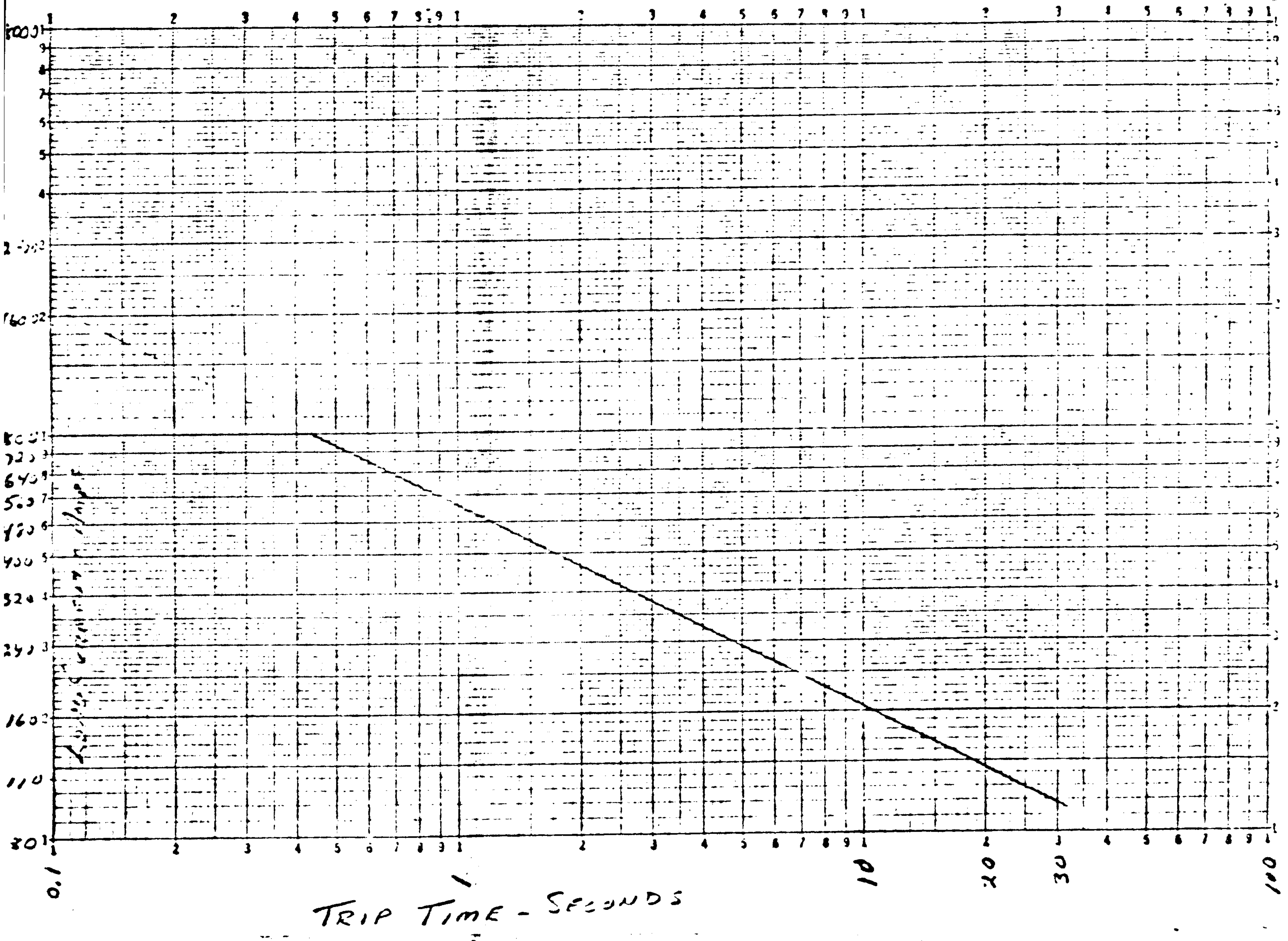
The output of the DC-DC inverter will be connected to the Voltage Regulator. Proper operation of the controllers requires a regulated supply voltage. A conventional voltage regulator circuit will be used.

8. Instantaneous Overcurrent Device

This unit has not been developed but the design goals have been set. The unit will be capable of sensing overload current using the shunt and removing the load instantaneously for a short circuit and in approximately 20 seconds for 110 amps. The attached graph is the proposed current versus trip time characteristics.

K·E LOGARITHMIC 359-112

Response Curve - Overcurrent Protection



9. Undervoltage Device

This unit has not been developed but will cause the load to be removed and shutdown the FCA when the voltages is below a pre-determined limit.

Instrumentation Readout:

The following readouts are the items of the Instrumentation Subsystem which will be monitored on the front panel. All other IS readouts will be available on the EMCS through a rear mounted connector. A dial will be provided to select KOH concentration.

1. Total Voltage
2. Total Current
3. Pressures O_2, H_2 & H_2O Cavity
4. Temperature
5. Deviation of % KOH-will utilize Water Removal Controller
6. Cool/Heat requirements - will utilize temperature controller

Manual Override:

The following functions will be capable of being manually controlled in the Manual mode of operation.

1.	Water Removal Cavity Valve	Open-Close-Auto
2.	Reactant (O_2 & H_2) Valves	Open-Close-Auto
3.	Primary Coolant Valves	Open-Close-Auto
4.	Purge (H_2 & O_2)	Manual - Auto
5.	Purge Controller	On - Off
6.	Auxilliary Power	On - Off

Indicating Devices:

The following indicating devices will show the state or condition of the device

1.	O_2 Inlet Valve	Open/Closed
2.	H_2 Inlet Valve	Open/Closed
3.	O_2 Purge	Open
4.	H_2 Purge	Open
5.	Water Removal Cavity Valve	Open/Closed
6.	Primary Coolant Valve	Open/Closed
7.	Over Temperature	
8.	Under Temperature	
9.	Over Current	
10.	Under voltage	
11.	Auxilliary Power	
12.	Mode of Operation	MAN-STBY-AUTO
13.	Load Contactor	Open/Closed

Development Area:

The development areas of the EMCS is to upgrade the laboratory breadboard models of the controllers for more reliable operation. The following are items that have not been developed.

1. DC-DC Inverter
2. Voltage Regulator
3. Auxilliary Master Control
4. Instantaneous Overcurrent Device
5. Undervoltage Device
6. Master Control

The Inverter and the Regulator will be conventional devices but will require design and laboratory development. The Auxiliary Master Control will be a mechanical subassembly and will be developed in conjunction with the Master Control. The Instantaneous Overcurrent device and Undervoltage device will require design and laboratory development to verify design goals. The Master Control has been partially designed in the Electrical Control Assembly 49-400-134-401 which outlines the front panel layout. The circuitry and associated electronics has yet to be developed.

4. Test Plan

Test Authorization Specifications will be written on components, sub-assemblies and the entire sub-system as the design progresses and is further developed.

P. D. Hess, Manager
Engineering Section

Attachments:
Appendix A
49-200-206-501
49-300-221
49-300-225
49-400-134-401

APPENDIX A

Outline of Electrical Protection and Control system as Covered by Single Line Diagrams Sketch 49-300-221

A Selector Switch '69' is turned to "Stand by" position which permits energization of all aux. electrically controlled devices such as Heater and Heater Switch 37, reactant controls, etc,. to be energized by operation of Startin PB. '1' provided the keyed lock-out device '86' has been manually placed into the "on" position. Manually operated Switch '8' connects the Aux. Control Bus to the start up Aux.Bus which is powered by a source other than the FCA. Switch 8x connects a 400 cycle 3 ∅ inverter to the blower motors M_1 and M_2 and Switch 8y connects a small DC to DC insulation inverter, and voltage regulator 90 to the 3 Wire Control Logic Bus which has its neutral wire directly connected to the positive terminal of the 100 MV 100A shunt of the FCA Systems. Proper surge control is obtained by referencing all wire shields to this Bus.. After all start up requirements have been met, the Selector Switch 69 is turned to "Manual". In this position, the Load Switch "72" may be closed by operating devices "72x". Each individual subcontroller, such as the Water Removal Control 20 Wx, Temperature Control 20 Tx, Purge Control 20 HOx, etc,., must be manually controlled and operated by operation of respective switches devices "1x". After proper FCA operation has been checked, the Selector Switch 69 is turned to "auto" which connects all electromechanical devices essential for proper FCA operation and protection to the Master Control Unit 4, Aux. Master

Control 4x and individual FCA performance controllers 20 Wx, 20 Tx, and 20 HOx.

Provision is made for manual override of automatic functions performed by controllers on an individually selected basis. 3 point Selective feature of any one of devices "1x" is maintained in the "Manual" Selector Switch 69 position. This arrangement permits maximum flexibility in the operation of the FCA for purposes of test and performance evaluation. Controls and device 76I, low voltage devices 27 and 27x, temperature control 20 Tx, etc., are maintained functionally independent of manually operated controls for reasons of safety.

The key locked, electrically tripped, manually reset lockout device 86 is provided to permit re-energization of the FCA after a forced shutdown. Only an authorized person, namely the one who has the key to the lockout switch can take the FCA in operation. All control subassemblies will have binary type readout provision in the form of extra contacts of the latch type relays contained in the Aux. Master Control 4x. Pressure transducers such as device 20 WP or other analog type sensing devices will be fitted with readout terminals to be connected to readout equipment presently not covered by contract.